SEMI-OBJECTIVE FORECASTING OF ATMOSPHERIC STAGNATION IN THE WESTERN UNITED STATES

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ABSTRACT

Forecasts of air pollution potential by semi-objective means are demonstrated and shown to be useful in delineating stagnation areas associated with the quasi-stationary anticyclone and ridge aloft over the western United States. Past stagnation episodes i.e., prolonged periods of very low wind speed, variable wind direction, and pronounced atmospheric stability near the surface, were used in the preliminary tests of the forecast procedure; results obtained were sufficiently encouraging so that the forecast scheme was applied on a daily basis for the 4-mo. period beginning October 1962 and ending January 31, 1963. The effectiveness of the daily forecasts of high air pollution potential is shown by the air quality data collected during forecast periods of atmospheric stagnation.

1. INTRODUCTION

Air pollution potential has been defined meteorologically as a set of weather conditions conducive to the accumulation of air pollutants in the atmosphere over 36 hr. or more. Niemeyer [5], Boettger [1], and others found that these meteorological conditions most conducive to accumulation of atmospheric pollutants (i.e., hourly surface wind speeds not to exceed 7 kt., winds aloft not to exceed 25 kt., subsidence below 600 mb.) occur when there is high pressure at the surface and a warm-core type ridge aloft.

In analyzing the daily synoptic weather for impending episodes of high air pollution potential, the forecaster therefore looks first for the simultaneous occurrence of high pressure at the surface and a warm-core type ridge aloft. The warm-core ridge aloft is extremely important, since it tells the forecaster that surface pressure systems will move relatively slowly across the area beneath it. If a blocking situation develops, the surface anticyclone tends to become quasi-stationary and minor perturbations aloft and at the surface are forced to move around the system. Another significant feature is that a mature warm ridge is rarely associated with rapid changes.

U.S. Weather Bureau meteorologists, assigned to the U.S. Public Health Service, Division of Air Pollution at the Robert A. Taft Sanitary Engineering Center, began issuing forecasts of high air pollution potential for the area east of 105° W. longitude in August 1960. During the first year of this operation, from August 1960 to July 1961, 12 cases of air pollution potential occurred; of these, 10 were forecast (Miller and Niemeyer [4]).

Holzworth [3], in a climatological study of air pollution potential for the western United States, also found that the large-scale synoptic feature most conducive to poor air quality is the quasi-stationary anticyclone. This study and the initial success of the forecast program for the eastern United States provided the background for the first program for forecasting large-scale air pollution potential over western United States from September to December 1961. The information gained during this period and in previous stagnation cases was utilized in formulating the semi-objective technique of forecasting air pollution potential for the western United States.

2. THE METHOD

The discussion that follows outlines a semi-objective technique of depicting the stagnant areas associated with anticyclonic systems over the western United States (the area west of 105° W.). The technique is based on meteorological and air pollution data for the months of October, November, December, and January in the years 1957 through 1961.

This method was formulated with the basic definition of air pollution potential in mind. The main objective was to compare the "numbers" derived by this technique with observed synoptic features of atmospheric stagnation. To do this two factors describing the vertical features of stability and wind flow in two adjoining layers of the lower troposphere were formulated for use in predicting atmospheric stagnation for the ensuing 24 hr. These factors are computed on the basis of 1200 GMT rawinsonde data.

The "lower-layer factor," based on the 24-hr. estimate of vertical mixing (mixing height) and the average horizontal wind transport in the lower 1000 m. (surface to 1 km. above the surface) of the troposphere, is presumed to describe the stagnation potential in the lowest layer of the atmosphere. The extent of the vertical mixing, i.e., the mixing height, is obtained at the dry-adiabatic intersection of the predicted afternoon maximum temper-

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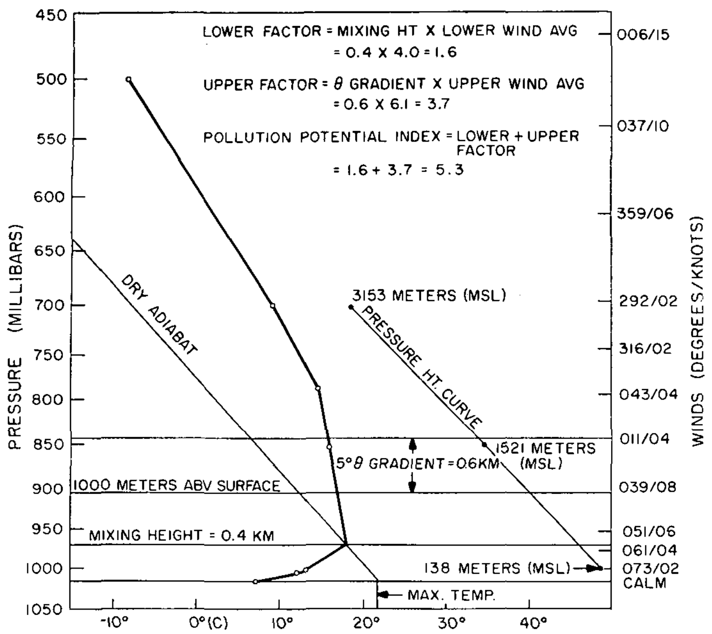

FIGURE 1.—Determination of pollution potential index for Oakland, Calif., on November 7, 1961 (based on 1200 GMT rawinsonde data).

ature with the 1200 GMT vertical temperature profile. The product of this predicted mixing height and the average horizontal wind speed (in knots) obtained from the 1200 GMT rawinsonde determines the lower-layer factor.[1]

An "upper-level factor," based on stability and wind conditions at 1200 GMT from 1 km. above the surface to 6 km. (mean sea level), is combined with the lower-layer factor in a final evaluation of atmospheric air pollution potential. The degree of stability occurring approximately 1.2 km. above the surface is assessed by computing the thickness of a 5° C. potential temperature gradient, using 1 km. above the surface as the base of this gradient. Experience has shown this upper-level stability index to be a good indicator of the degree of subsidence existing in the lower troposphere. The product of this stability index and the average wind speed (in knots) from 1 km. above the surface to 6 km. (mean sea level) gives the upper-level factor. The sum of the lower-level and upper-level factors gives a number that is referred to as the pollution potential index.

An example of this semi-objective forecast procedure is shown in figure 1. In this case, the maximum temperature [2] (22° C.), taken dry adiabatically to the intersection of the temperature profile, gives a mixing height of 0.4 km. To compute the lower factor, we multiply 0.4 times the average wind speed from surface to 1 km. above the surface, which in this case is 4.0 kt. The lower-level factor, therefore, is 1.6.

To compute the upper-level factor, we first draw the pressure height curve. From this curve, we can find the point on the temperature profile that is 1 km. above the surface. Since the station elevation at Oakland is 5 m., the point is 1005 m. on the pressure height curve. This point, 903 mb., is the base of the 5° C. increase in potential temperature; the top of this 5° change is at 840 mb. The thickness of this upper-level stability layer is 0.6 km., while the upper-level average wind speed from 1 km. above surface to 6 km. mean sea level is 6.1 kt. The product of these two values gives an upper-layer factor of 3.7. The sum of the lower-level and upper-level factors yields a pollution potential index of 5.3 for Oakland on this day.

3. DETERMINATION OF SIGNIFICANT POLLUTION POTENTIAL INDEX NUMBERS

It was necessary to establish some significance for the pollution potential index numbers before they could be used in a forecast scheme. Since the objective is to forecast air pollution potential on a synoptic scale, the index of pollution potential should have similar meanings over all the western United States. This idea was investigated by utilizing climatological data (U.S. Weather Bureau [8, 9]) and National Air Sampling Network (NASN) data (U.S. Public Health Service [6, 7]) for selected cities during the months of October, November, December, and January from 1957 through 1961. It was necessary that the cities selected for this investigation have Weather Bureau rawinsonde stations and also be participating members of the NASN.[3] The cities chosen for this part of the study were Albuquerque, Berkeley, Boise, Las Vegas, Long Beach, Los Angeles, Oakland, and Salt Lake City.

A pollution potential index number was computed for each day on which a 24-hr. high volume particulate sample was collected at each city. These samples were classified according to yearly rank (particulate concentration) and meteorological conditions (cyclonic or anticyclonic circulation, precipitation, winds aloft) during the sampling period. The individual classified samples were then plotted at the point of intersection of the associated 24-hr. average surface wind speeds and computed pollution potential index numbers. Figures 2 through 5 show the scatter diagrams plotted for Albuquerque, Boise, Los Angeles, and Salt Lake City.

The next step in determining a significant pollution potential index number was to eliminate all samples, represented by the symbols U and L, for which meteorological cinditions were not conducive to pollutant accumulation. Among these were some samples collected under

[1] The average horizontal wind transport in the lower-layer factor and the upper-layer factor is a vertically averaged layer wind and is computed from 1200 GMT rawinsonde data.

[2] Observed maximum temperatures were used in computing the mixing heights for all test cases listed in table 2. On a daily basis, forecast maximum temperatures are used in finding mixing heights.

[3] National Air Sampling Network Stations take air quality measurements on a random basis. One 24-hr. sample is taken during each 2-week period.

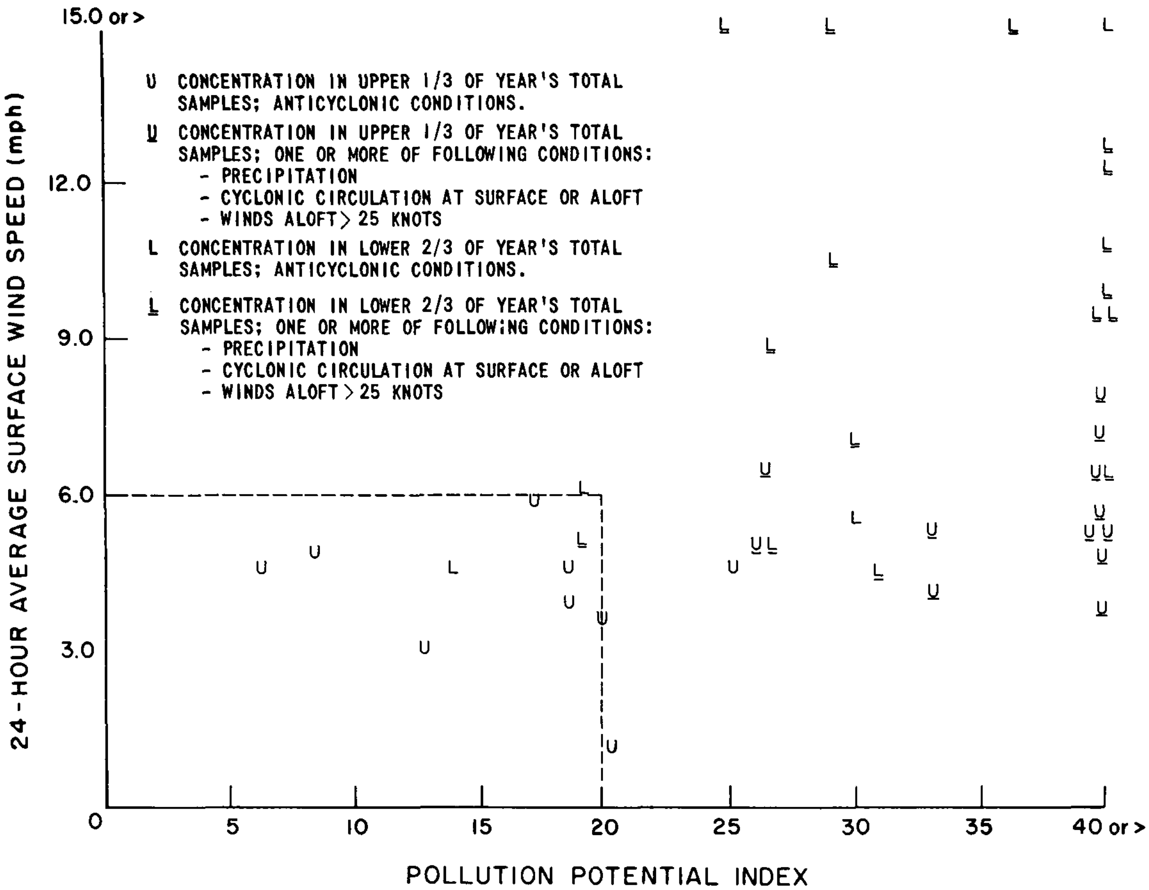

FIGURE 2.—Distribution of particulate samples by wind speed and forecast number: Albuquerque, N. Mex.

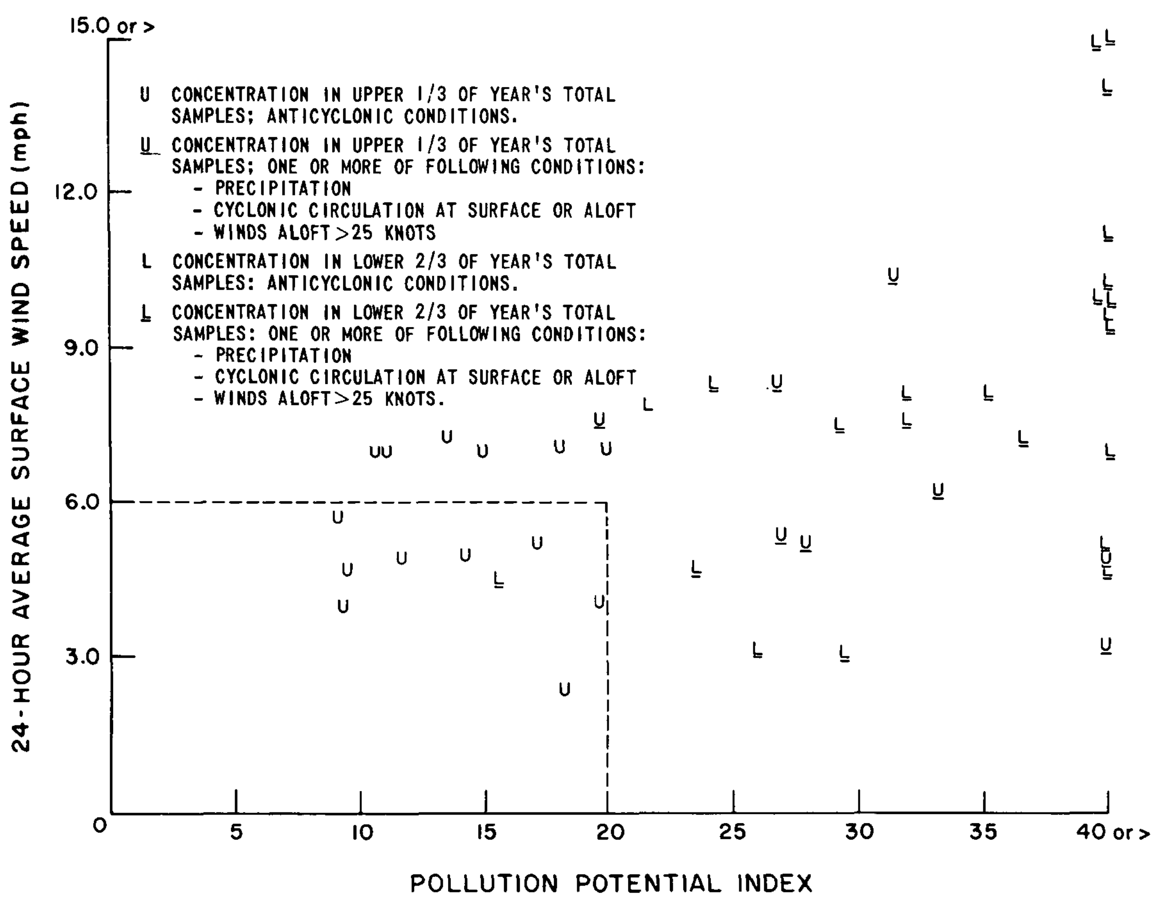

FIGURE 3.—Distribution of particulate samples by wind speed and forecast number: Boise, Idaho.

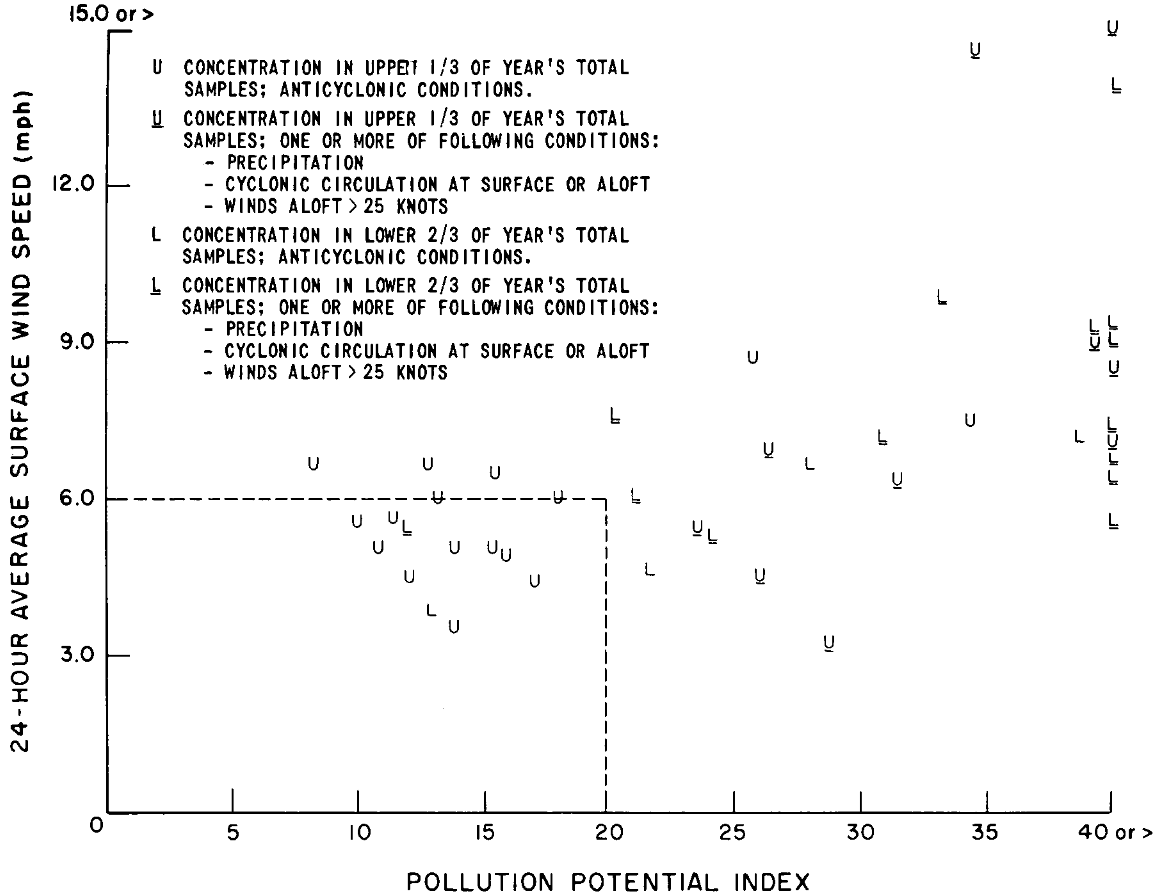

FIGURE 4.—Distribution of particulate samples by wind speed and forecast number: Los Angeles, Calif.

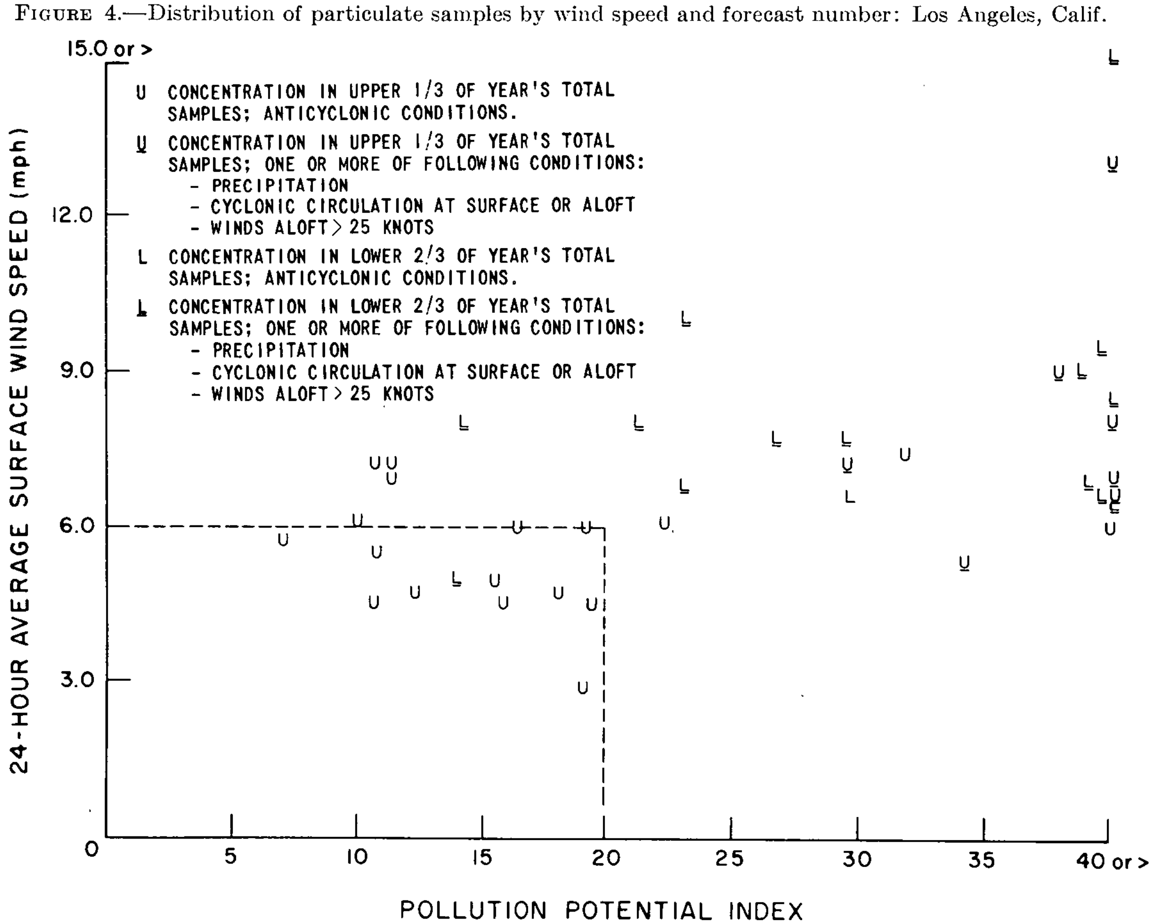

FIGURE 5.—Distribution of particulate samples by wind speed and forecast number: Salt Lake City, Utah.

anticyclonic conditions; however, the winds aloft during the collection of these samples greatly exceeded 25 kt. Those samples that remained in categories U and L, were collected under anticyclonic conditions that met the requirements for air pollution potential. Of the samples represented by the symbols U and L, 89 percent fall in the ≤ 20 range of the computed pollution potential index numbers. Without exception the significant pollution potential index number for Berkeley, Las Vegas, Long Beach, and Oakland was also 20.

Usually when a city is experiencing high air pollution potential, the particulate loadings are higher than normal. On the basis of 20 as the significant pollution potential index number, 95 percent of the samples collected at Alburquerque, Boise, Los Angeles, and Salt Lake City were found to be in the upper third of all samples collected during the year. Therefore, under anticyclonic conditions during the months of October, November, December, and January, it was deduced that air pollution potential may be expected to occur in areas over western United States where the computed pollution potential index is ≤ 20.

A rather simple approach was adopted in applying this significant pollution potential index number as an indicator of air pollution potential. The index numbers computed for each rawinsonde station are plotted on a map and an isoline analysis is made. Areas enclosed by the number 20 or less depict the areas where conditions favorable to air pollution potential are most likely occurring. If these conditions are expected to continue over an area approximating a 4° lat. square (or larger) for 36 hr. or more, the forecaster uses the isoline analysis as a guide in preparing the day's forecast.[4]

4. VERIFICATION PROCEDURE

The procedure used to verify the technique and the pollution potential index numbers entails two steps. The first step is to check the available air quality data for cities in the forecast areas. Ideally, this is the only way verification should be made. However, the paucity of such data makes it desirable to verify air pollution potential forecasts via wind movement; therefore the second step is to examine the daily average surface wind speeds within the forecast area. The use of air quality data collected during periods of high air pollution potential is an obvious verification procedure, but some explanation is needed for the use of average daily surface wind speeds to verify forecasts of high air pollution potential. Within a given geographical area, the importance of surface ventilation varies according to terrain and air pollution sources. For this reason a specific significant value of average surface-wind speed is difficult to determine. It is possible, however, to designate a value that is in keeping with the 7-kt. (8.1 m.p.h.) hourly wind limit described by Niemeyer and that is useful in verifying air pollution potential forecasts. Among the average wind speed values associated with the samples represented by the symbol U (figs. 2–5) in the 0–20 forecast range, 44 percent fall in the $<$5-m.p.h. range, 74 percent in the $<$6-m.p.h. range, and 90 percent in the $<$7-m.p.h. range.

The author finally designated 6 m.p.h. as the average wind speed for use in verification of these forecasts.[5] (Too many hourly winds exceeded 7 kt. when the 24-hr. average wind speed exceeded 6 m.p.h.) It was determined, therefore, that under stagnating anticyclonic conditions, a pollution potential index (PPI) number of 20 or less can indicate to the forecaster an area in which pollutant concentrations are expected to be above normal and the majority of the hourly average surface wind speeds are expected to be less than 6 m.p.h. for the ensuing 24-hr. period. These limits, 20 PPI and 6 m.p.h., are represented by the dashed lines in figs. 2–5.

5. TEST AND APPLICATION

Past stagnation episodes were used in the preliminary tests of the technique just described. A brief résumé of one of these cases follows.

AIR POLLUTION POTENTIAL OF NOVEMBER 6–11, 1961

Analysis of the large-scale synoptic conditions of this case shows that a high-pressure system moved southward from Canada and settled over the Great Basin area on November 6, 1961. Figure 6 shows the 6-day mean 1000-mb. chart for this period and the daily location and strength of the surface high center at 0000 GMT. The center of the high pressure changed very little in intensity from the 6th to the 9th, but thereafter the High weakened. Cyclonic flow in association with a Pacific cold front entered the northwestern United States on the 9th. This front continued southward and resulted in the termination of the episode on the 11th.

Figure 7 shows the 6-day mean 500-mb. chart for this same period. It is particularly interesting to note the $-15°$ C. isotherm, which shows the extent of this warm-core ridge. On the 6th and 7th, there was a cut-off Low at 500 mb. centered over the Baja California peninsula. After the 7th, this Low moved steadily northeastward. On the 6-day mean 500-mb. chart, this Low was centered over northeastern New Mexico. A long-wave 500-mb. trough, which began to move into the northwestern United States along with the surface cold front on the 9th, covered all the western United States on the 11th. Figure 8 shows in detail the computed forecast area of high air pollution potential, the area with 24-hr. average wind speeds of 6 m.p.h. or less, and the area in which the defining criteria for air pollution potential were met on November 7, 1961.

In verification of the forecasts, examination of the 24-hr. average surface wind speeds within the forecast areas

[4] For the test cases listed in table 2, areas enclosed by the number 20 or less were also considered the forecast areas of air pollution potential.

[5] The State of California [2] uses average wind speeds of 6¼ m. p. h. or less as a rough measure of "daily pollution potential".

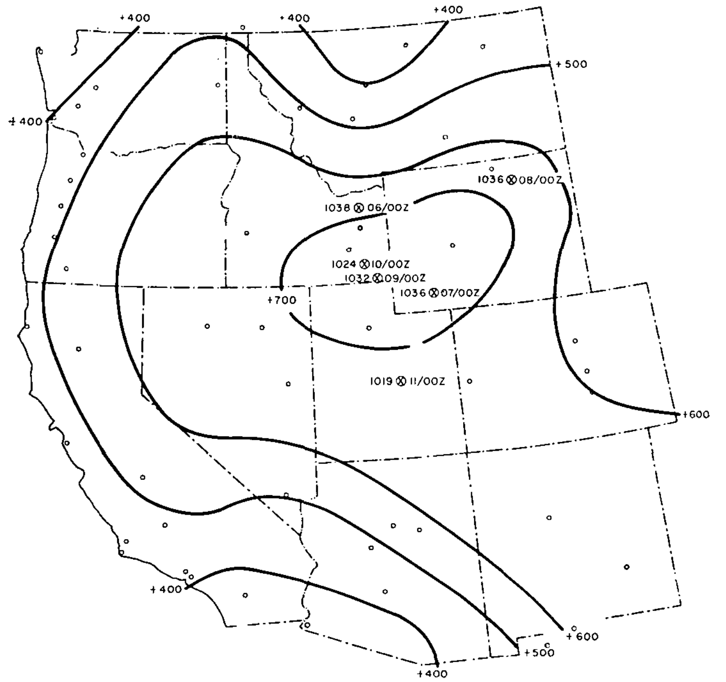

FIGURE 6.—Observed 6-day mean 1000-mb. chart with daily location and intensity of surface High: November 6–11, 1961.

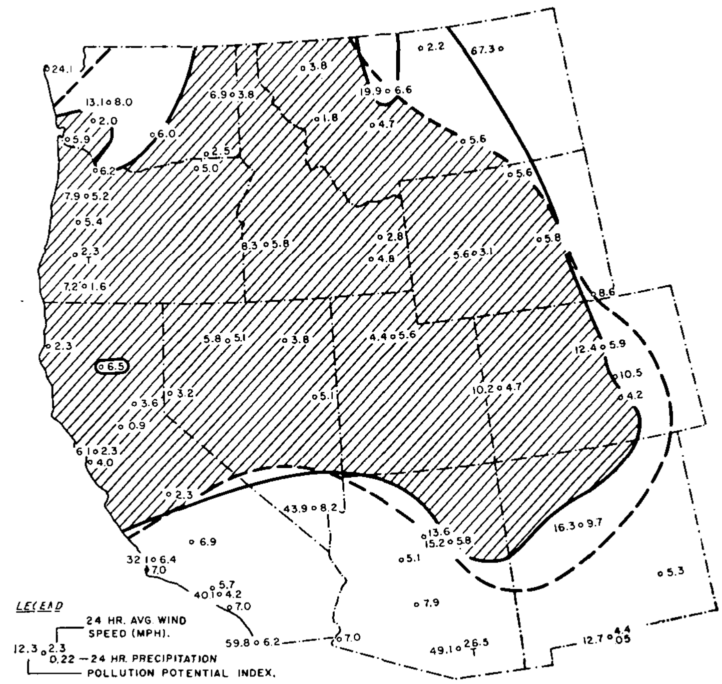

FIGURE 8.—Area of pollution potential, November 7, 1961. Solid line encloses areas in which daily average wind speeds were 6 m.p.h. or less. Dashed line encloses the area in which the pollution potential index numbers are less than or equal to 20. Shading covers areas in which the defining criteria for air pollution potential were met.

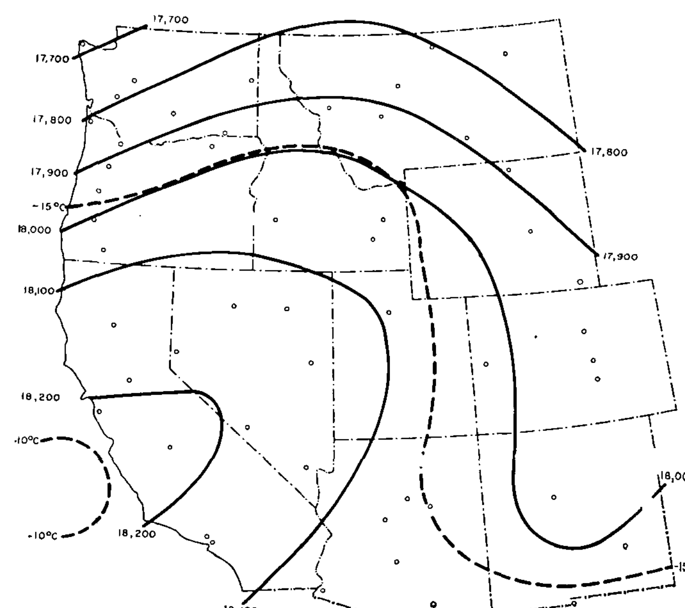

FIGURE 7.—Observed 6-day mean 500-mb. chart: November 6–11, 1961.

showed that about 88 percent of the reported wind speeds were less than 6 m.p.h. A number of the wind speeds greater than 6 m.p.h. within the forecast areas occurred at typically windy places (Holzworth [3]) such as Ely, Boise, Red Bluff, and Pendleton. The air quality data shown in table 1 provide further verification of the forecasts. During the forecast period, 23 high-volume particulate samples were collected at 12 cities. Of these, concentrations in 15 samples were among the five highest collected at the individual stations during the year. All but one of the remaining eight fell in the upper third of all samples collected for the year.

In addition to the case just described, 15 other stagnation episodes were investigated by use of this same technique. Table 2 lists these cases by year and month. Results obtained from these cases were so encouraging that the forecast scheme was applied on a daily basis for the 4-mo. period beginning October 1, 1962 and ending January 31, 1963.

THE FOUR-MONTH STUDY

The purpose of the 4-mo. project was to investigate further the relationship of the daily forecasts of high air pollution potential to daily community air pollution levels. Six stations of the National Air Sampling Network cooperated in this project by collecting daily high-volume particulate samples; 15 other NASN stations collected additional (non-scheduled) samples only during stagnation conditions.

During this test period, eight episodes of atmospheric stagnation occurred; all were forecast by means of the semi-objective technique. Air quality data collected during these periods of stagnation by cities not sampling on a daily basis were compared with the mean monthly particulate value for those cities. Tables 3 through 6

TABLE 1.—*Comparative air quality data taken during the period November 6–11, 1961*

City	Yearly rank of sample taken during alert (rank/number of samples)	Concentration (micrograms per cubic meter)			
		Sample taken during alert	Yearly average	Yearly maximum	Yearly minimum
Denver	8/25	108	115	341	48
Boise	1/34	260	112	260	27
Boise	2/34	179	112	260	27
Boise	5/34	160	112	260	27
Seattle	2/28	211	93	361	43
Seattle	3/28	169	93	361	43
Seattle	7/28	102	93	361	43
Eugene	7/22	103	87	158	23
Phoenix	8/27	268	220	449	93
Salt Lake City	2/28	333	147	407	36
Salt Lake City	4/28	246	147	407	36
Salt Lake City	5/28	229	147	407	36
Berkeley	1/35	286	106	286	20
Berkeley	2/35	228	106	286	20
San Francisco	1/33	188	72	188	20
San Francisco	7/33	96	72	188	20
San Jose	2/34	226	118	302	50
San Jose	4/34	198	118	302	50
San Jose	5/34	191	118	302	50
San Jose	8/34	146	118	302	50
Los Angeles	8/34	223	181	399	83
San Diego	17/29	85	95	195	45
Long Beach	2/28	220	140	283	65

TABLE 2.—*Episodes of quasi-stationary anticyclones studied to determine the usefulness of the semi-objective forecast procedure*

	January	October	November	December
1957			21–26	9–10
1958	5–8	15–16	20–24 28–D3	N28–3 15–19
1959			6–12 27–D3	N27–3
1960				11–13
1961	2–8	2–5	6–11	
1962	*26–Feb. 3			

*Quasi-stationary anticyclonic episodes during October, November, and December 1962 are not included in the Table.

show these comparisons. A graph showing the daily particulate values was prepared for each city that sampled daily during the 4-mo. period. Because of seasonal variation in mean pollution levels, a 15-day running mean was computed and plotted for each of these cities and was used to establish periods of relatively high values. Values were considered high when they were 20 percent or more greater than the 15-day mean. Figures 9 and 10 show these graphs for Berkeley and Long Beach, Calif.

Through these months, there appears to have been only one extended period in which particulate air pollution levels were high and air pollution potential was not forecast. Particulate values at both Berkeley and Long Beach (figs. 9 and 10) showed greater than the 20 percent deviation from the mean on November 17 to November 23, 1962, but no forecast was issued. Anticyclonic flow prevailed over most of California throughout this period; in general the winds below the mixing height were light, but winds above this height were much too strong for a forecast of air pollution potential. This incident indicates that although the majority of extended air pollution buildups occur under general air pollution potential conditions, exceptions do occur.

TABLE 3.—*Comparison of particulate values during 1962 forecast periods with mean particulate values: October**

City	Concentration (micrograms per cubic meter)			
	Minimum	Maximum	Monthly mean	Samples taken during October 1962 stagnation periods
Phoenix	86	449	235	302
Fresno	83	304	179	95 116 137 186 204
Los Angeles	106	296	203	179
Oakland	64	243	138	160
Sacramento	36	264	124	67 134 115 167 123 169
San Bernardino	167	336	254	305 383
San Francisco	17	136	76	27 73 166
San Jose	83	232	140	158 205 260 177 223 203 234
Stockton	60	238	147	81 81 88 149
Portland	62	235	151	313

*National Air Sampling Network Data (1958, 1962) for the years 1953–62 was used in computing the monthly mean, maximum, and minimum.

TABLE 4.—*Comparison of particulate values during 1962 forecast periods with mean particulate values: November**

City	Concentration (micrograms per cubic meter)			
	Minimum	Maximum	*Monthly* mean	Samples taken *during* November 1962 stagnation periods
Phoenix	86	416	273	446 493
Tucson	91	270	191	215
Fresno	55	201	114	184 197 246 265
Sacramento	22	236	124	151 159 169
San Bernardino	53	453	238	214 231 251
San Diego	80	157	122	145 206
San Francisco	43	238	99	155 162 207
San Jose	37	307	143	150 193 194
Stockton	93	316	160	137 163 172
Denver	60	311	136	113
Seattle	41	102	73	90 109 205 216

*National Air Sampling Network Data (1958, 1962) for the years 1953–62 was used in computing the monthly mean, maximum, and minimum.

6. SUMMARY AND REMARKS

The study presented gives a semi-objective method of forecasting air pollution potential associated with the quasi-stationary anticyclone and ridge aloft over the western United States. This technique was formulated with the basic definition of air pollution potential in mind and with the main objective being to compare forecasts made by this technique with actual synoptic features of

TABLE 5.—*Comparison of particulate values during 1962 forecast periods with mean particulate values: December**

City	Concentration (micrograms per cubic meter)			
	Minimum	Maximum	Monthly Mean	Samples taken during December 1962 stagnation periods
Phoenix	60	573	334	317 370 340 371 362 415
Tucson	20	521	201	122 257 203 359 229
Fresno	87	372	177	56 159 218 231 58 176 221 310 114 184 224 375
Los Angeles	70	594	265	116 175 222 329 157 179 289 409 162 215 307
Oakland	67	289	136	109 126 169
Sacramento	26	403	131	42 71 84 56 72 100 66 81 135
San Bernardino	43	272	147	123 231 338 603 152 253 362 621 205 313 431
San Diego	79	246	156	94 121 167 195 108 121 170 207 112 129 183 209
San Francisco	42	253	125	83 108 149 165 86 122 149 206 95 146 152
San Jose	25	303	148	127 207 246 189 210 257 203 237 306
Stockton	None available			40 49 61 45 50 69 49 57 79
Medford	None available			123 159 181 263
Portland	30	250	106	57
Seattle	41	142	84	56 90 124 266

*National Air Sampling Network Data (1958, 1962) for the years 1953-62 was used in computing the monthly mean, maximum, and minimum.

TABLE 6.—*Comparison of particulate values during 1962 forecast periods with mean particulate values: January**

City	Concentration (micrograms per cubic meter)			
	Minimum	Maximum	Monthly Mean	Samples taken during January 1963 stagnation periods
Fresno	18	154	70	130 187 273 303 130 190 285 150 219 302
Los Angeles	58	333	181	172 207 274 315
Oakland	47	243	135	137 146 252 329
Sacramento	36	149	77	97 159 200 106 163 128 178
San Bernardino	35	167	112	316
San Diego	67	181	122	68 119 115 178 115
San Francisco	45	184	124	132 149 154
San Jose	23	302	147	154 175 165 241 174
Stockton	None available			98 134
Portland	34	392	135	136 166 174 182
Phoenix	120	440	303	126 215 309
Tucson	62	308	156	115

*National Air Sampling Network Data (1958, 1962) for the years 1953-62 was used in computing the monthly mean, maximum, and minimum.

atmospheric stagnation. Past episodes of atmospheric stagnation were used in the preliminary tests of the forecast procedure and results were sufficiently encouraging that the method was used on a daily basis for the 4-mo. period beginning October 1, 1962, and ending January 31, 1963.

The effectiveness of the daily forecasts of high air pollution potential is shown by the air quality data presented in tables 3–6 and figures 9 and 10. Seventy-one percent of the high-volume particulate samples collected under air pollution potential conditions by those cities listed in these tables were above the monthly mean. In figures 9 and 10, 83 percent of the particulate samples that were 20 percent or more greater than the 15-day mean were taken on days for which air pollution potential was forecast.

Problems involving both sampling and forecasting were observed; examples of these problems are drawn from the air pollution potential episode of December 4 to 16, 1962. Since Los Angeles and Long Beach, Calif., are in the same metropolitan area, one might assume that the same general pollution trend (up or down) should be noted by each station. Such an assumption is not always valid, and this is one of the main problems with single-station sampling. For example, during this period air quality data should have shown above normal particulate values; on the 6th the particulate sample at Long Beach was considerably above its mean ($340\mu g./m.^3$), while the sample at Los Angeles was just below its mean ($262\mu g./m.^3$); on the 7th the Long Beach sample was much below its mean ($156\mu g./m.^3$), while the sample at Los Angeles was much above ($409\mu g./m.^3$). These data also indicate the importance of wind direction with respect to the distribution of pollutants. From December 4 to 16, 1962, 70 percent of the particulate concentrations in samples collected were substantially above normal at all stations except Sacramento and Stockton, Calif. Similar meteorological conditions existed at these cities, located in the heart of the Sacramento and San Joaquin Valleys, but of the 13 samples collected at these sites none was exceedingly high. During a similar stagnation episode in December 1961 sampling data from these two cities showed similar patterns, with little deviation from normal concentrations. A comprehensive study of these areas during such cases would be most interesting.

It should be emphasized that this study was only for the months of October, November, December, and January. Further study will be needed before this forecast method can be applied to the remaining months. Because this procedure was designed for use on a large synoptic scale, many local features could not be considered.

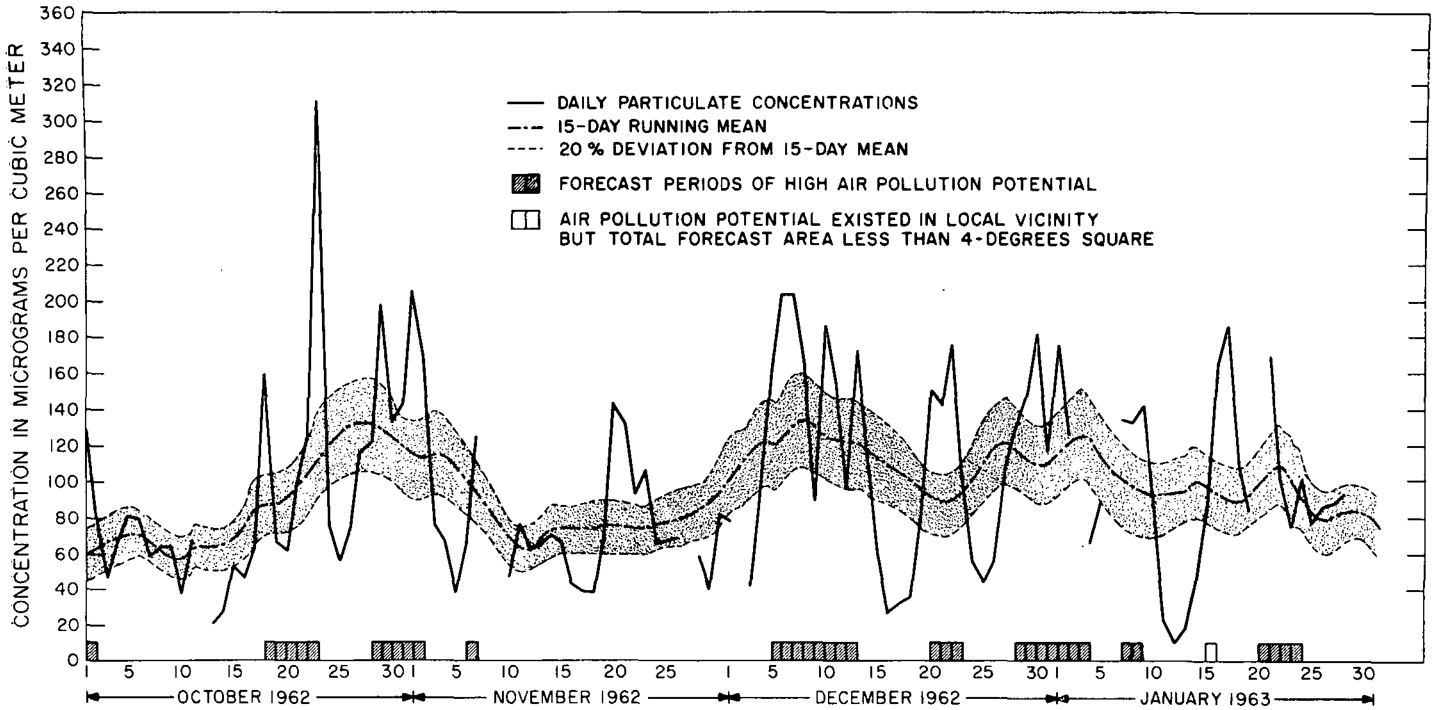

FIGURE 9.—Daily particulate values, Berkeley, Calif., October 1, 1962–January 31, 1963.

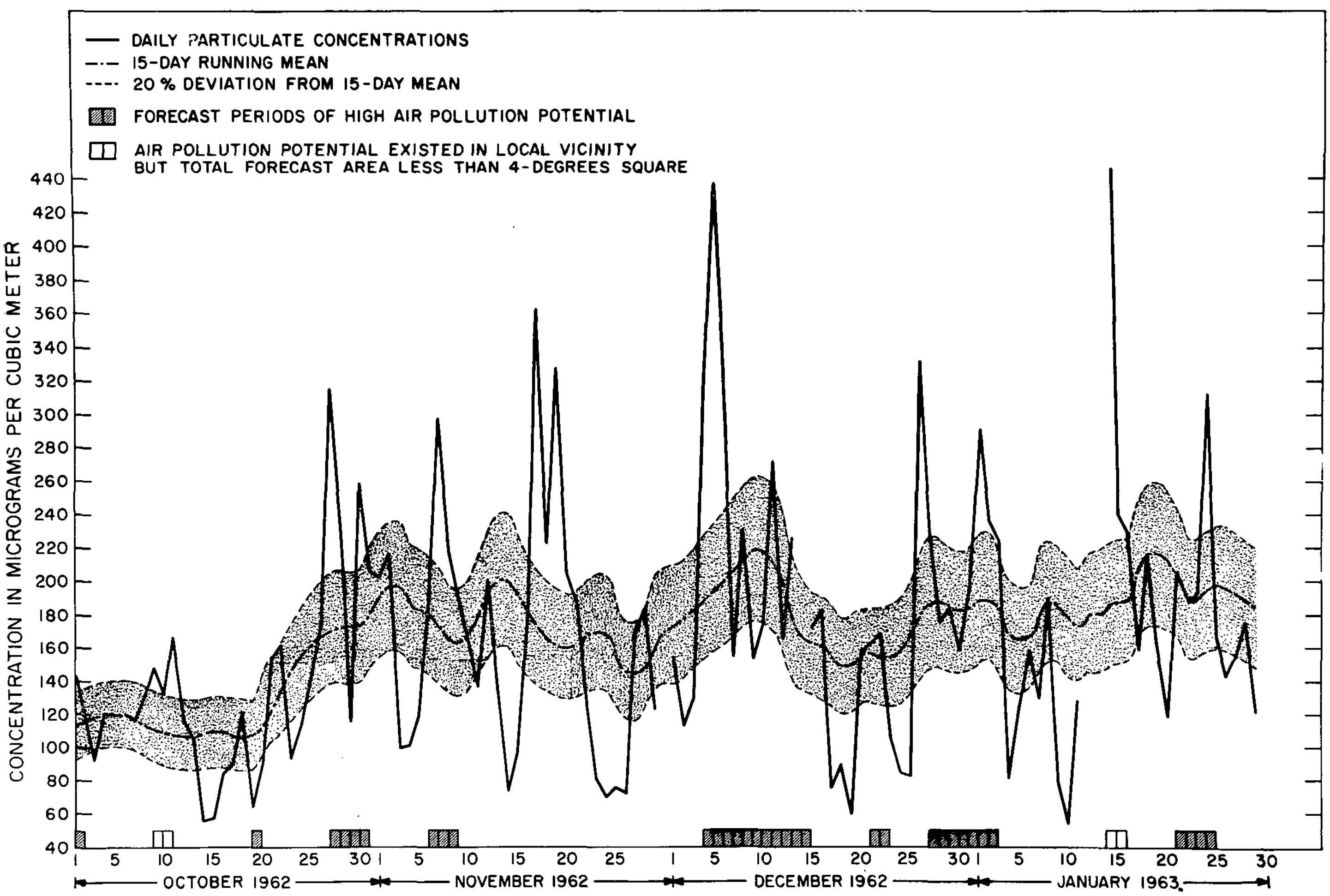

FIGURE 10.—Daily particulate values, Long Beach, Calif., October 1, 1962–January 31, 1963.

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New Weather Bureau Publications

Research Paper No. 44, "Three-Dimensional Wind Flow and Resulting Precipitation in a Northern California Storm," by Vance A. Myers and George A. Lott, Aug. 1963, 46 pp. Price 35 cents.

By careful consideration of the observed winds and with the aid of various empirical and dynamic relationships, a steady-state 3-dimensional wind flow is deduced over northern California for a 24-hour stormy period. The production (or evaporation) of precipitation elements is estimated for all parts of the flow, the surviving elements are followed down to the surface, and the resulting precipitation pattern is compared with the observed.

Technical Paper No. 47, "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska," by John F. Miller, 1963, 69 pp. Price $1.00.

PMP and rainfall-frequency data are given for areas to 400 sq. mi., durations to 24 hr., and return periods from 1 to 100 yr. Basic precipitation data were obtained from 234 Alaskan and 33 Canadian stations.

Technical Paper No. 2, Revised, "Maximum Recorded United States Point Rainfall for 5 Minutes to 24 Hours at 296 First-Order Stations," by A. H. Jennings, 1963, 56 pp. Price 40 cents.

Technical Paper No. 2 was first published in 1947. This revision brings the material up through 1961. A total of 338 new maxima were observed in the interim.

Climatography of the United States No. 21–46–2, "Climatic Summaries of Resort Areas—White Sulphur Springs, West Virginia," by J. K. McGuire, July 1963, 4 pp. Price 5 cents.

This is the third pamphlet in the series on resort areas in the United States. The others deal with Saratoga Springs, N.Y. and Berkeley Springs, W. Va.

Sheet of the *National Atlas* "Normal Annual Total Precipitation (inches)" and "Normal Total Precipitation (inches) by Months". 1 sheet. Price 10 cents.

The above publications are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Recent Articles in Other Weather Bureau Periodicals

Weekly Weather and Crop Bulletin, National Summary, vol. L

- No. 24, June 17, 1963:
  - "How Cooperative Observers' Records Are Used," by J. H. Hagarty, p. 8.
- No. 30, July 29, 1963:
  - "Northeast Drought in 1963?", a collection of reports from Weather Bureau State Climatologists in the Northeast, p. 8.
- No. 37, September 16, 1963:
  - "Harvesting Quality Cotton," by J. A. Riley, p. 8.
- No. 45, November 11, 1963:
  - "Northeast Drought of 1963," by State Climatologists, Northeast area, pp. 7–8.

Mariners Weather Log, vol. 7

- No. 4, July 1963:
  - "What Satellite Data Cannot Tell Us About Tropical Cyclones," by Neil L. Frank, pp. 113–116.
  - "A Look at ICITA," by Albert M. Bargeski, pp. 116–119.
- No. 5, September 1963:
  - "Surface Processes Which Contribute to the Decay of Hurricanes," by Banner I. Miller, pp. 147–149.
  - "A Study of Wave Persistence in the North Atlantic Ocean," by J. M. Kipper and E. J. Joseph, pp. 149–169.
- No. 6, November 1963:
  - "Pitching on a Prayer," by I. F. Wood, pp. 193–197.
  - "New Marine Climatological Exchange Program Adopted by WMO," by H.C. Sumner, pp. 197–199.